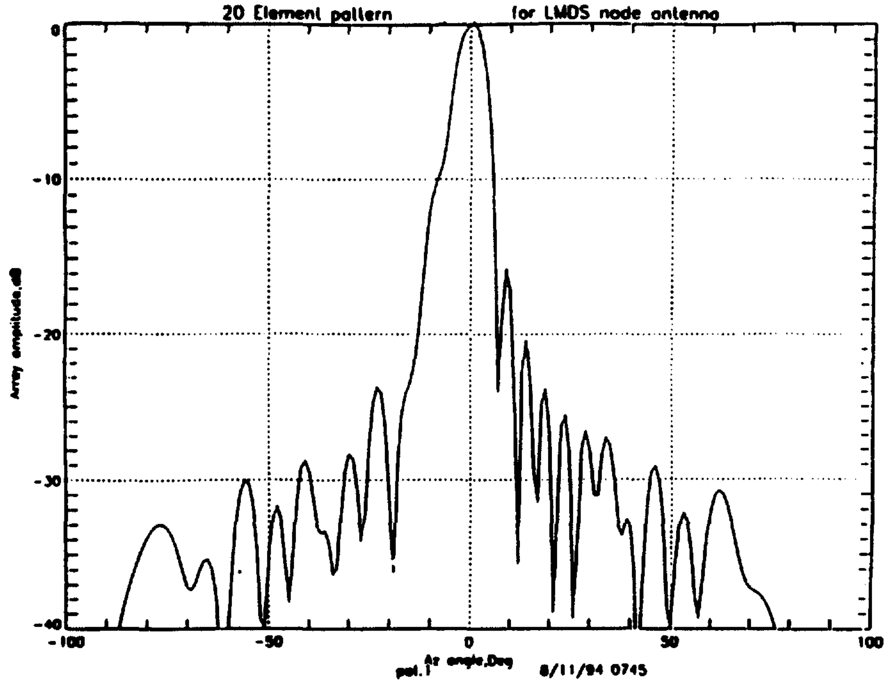
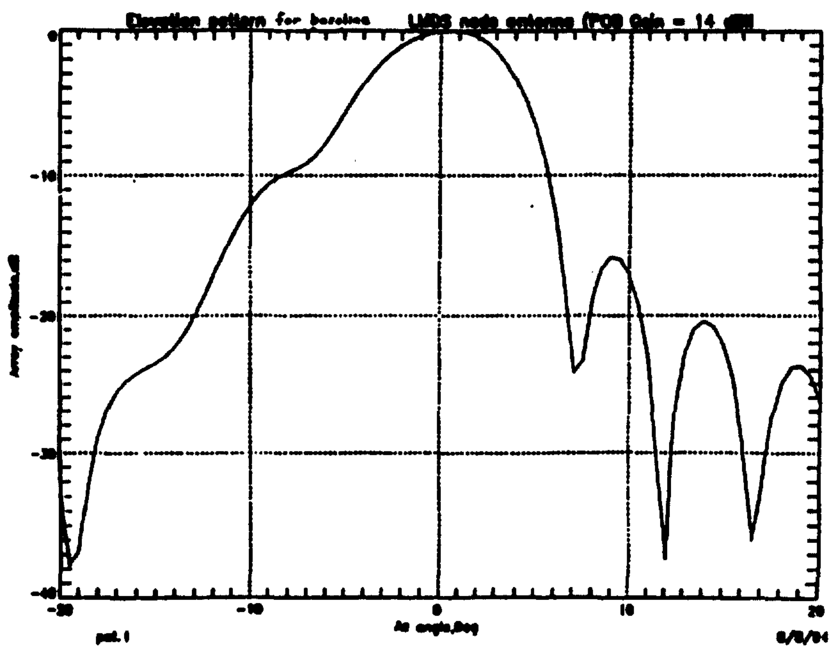


(a)



(b)

Exhibit 3. TI 14 dB gain hub antenna pattern

[Sources: (a) WG1 / WG2, 8/17/94; (b) JSTG 6, 8/9/94]]

Exhibit 4 presents the results of this analysis. Subscribers at ground level are considered to be in the most vulnerable position, so these positions are examined at horizontal distances from the hub of 2000 ft to 100 ft. The higher the hub tower, the greater the angle from boresight experienced at the ground: we used two tower heights corresponding approximately to 12-15 story building rooftops, cited by CellularVision as the expected locations of hubs[6]. At the shorter horizontal distances, the off-boresight angle falls off the main beam and onto the sidelobes, resulting in antenna pattern losses of 25 - 40 dB in some cases. However, there is an effective gain with respect to the cell edge in terms of path loss and rain loss due to the decreased signal path length. At each of the horizontal distances, the effective gain exceeds the antenna pattern loss comfortably, even in the nulls of the antenna pattern. Because neither the 14 dB antenna pattern nor the 12 dB pattern show any potential problem, it is clear that the LMDS 12 dB antenna gain may be increased to 15.3 dB without compromising near-in subscribers.

Transmitter Antenna Implementation Loss CellularVision's claim that "implementation losses" at 41 GHz will cause a 1 dB "penalty" is also without basis. Antenna materials and fabrication techniques at 28 GHz and 41 GHz are similar, and there is no reason to expect significant gain degradation at 41 GHz over that available at 28 GHz; and even if some degradation did occur, a slight increase in antenna vertical aperture size would restore the antenna to the desired gain/beamwidth performance levels, with no increase in cost.

Conclusion for 41 GHz Transmitter Antenna Gain:
CellularVision assumed value:~~11 dBi~~
Correct Value:15.3 dBi

[6] see [REF: WG1,WG2, 8/12/94]

Horiz. Distance:	2000 ft	1500 ft	1000 ft	500 ft	100 ft
Path Loss:	-18.0	-20.5	-24.0	-29.4	-37.0
Rain Loss:	-11.4	-11.8	-12.2	-12.6	-12.8
Total Gain:	+29.4	+32.3	+36.2	+42.0	+49.8
150 ft Tower					
Off-BS Angle:	4.3°	5.7°	8.5°	16.7°	56.3°
12 dB pattern:	5 dB	6 dB	10 dB	<25 dB	<40 dB
14 dB pattern:	5 dB	7 dB	10 dB	24 dB	40 dB
250 ft Tower					
Off-BS Angle:	7.1°	9.5°	14.0°	26.6°	68.2°
12 dB pattern:	8 dB	19 dB	<25 dB	<30 dB	<40 dB
14 dB pattern:	9 dB	12 dB	23 dB	<34 dB	<40 dB

Notes for Exhibit 4:

Note 1. Total rain loss at cell edge assumed: 13.0 dB

Note 2. Average of two towers (200 ft) used as vertical distance to subscriber in determining relative path and rain losses.

Exhibit 4. Comparison of pattern losses with relative gains in path and rain losses referenced to 3 mile cell edge, for a subscriber at the ground, as a function of horizontal distance from hub.

Receiver Antenna Gain

The CellularVision claim that a subscriber antenna operating at 41 GHz that is the same physical size as one operating at 28 GHz would have 3 dB less gain is just as unfounded as their incorrect claims for the hub transmit antenna. CellularVision arrives at the 3 dB value from two components: (1) a 4 degree beamwidth must be maintained because of "operational constraints", and, (2) an additional "two to four dB" degradation because of "reduced electrical efficiency" and "temperature sensitivity", resulting in degraded sidelobe supression and cross-polarization isolation. Both of these claims are absurd, as we demonstrate below.

Receive Antenna Beamwidth. CellularVision expresses the desire to maintain subscriber antenna beamwidth at 4 degrees or more for reasons of ease in pointing, installation, and stability. With the major benefits of greater coherence over a wide bandwidth due to antenna cancellation of incoherent multipath, and several dB potential added gain, it is well worth the small additional effort which may be required to initially align the antenna to allow the beamwidth to decrease. Precedent in the use of very tight beamwidths is found in the urban experimental study by the U.S. NTIA and U.S. Army[7] which showed benefits with beamwidths as small as 1.2 degrees, and pointing problems only for mobile terminals.

Receive Antenna Efficiency. Some reduction in antenna efficiency when operating at 41 GHz versus 28 GHz can be expected, but the magnitude of the efficiency loss assumed by CellularVision is completely unjustified. The severe 2 to 4 dB degradation asserted by CellularVision for the receive antenna implies a patch antenna solution, however a reflector antenna would not suffer this degradation, and is a low cost

[7] see E.J. Violette, R.H. Espeland, R.O. DeBolt, and F. Schwering, "Millimeter-wave propagation at street level in an urban environment," *IEEE Trans. Geoscience and Remote Sensing*, Vol. 26, No. 3, May 1988.

alternative. A reduction of 3 dB in antenna gain, as assumed by CellularVision, would require a reduction in antenna efficiency to about 28%, from a value of 50%. This drastic reduction is not predicted by any reasonable antenna analysis nor expected by any reputable antenna manufacturer. Reliable estimates indicate that antenna efficiency for a parabolic reflector, which would be a reasonable alternative at 41 GHz, where size is not a detriment, would degrade by about 5%, to a value of about 50% at 41 GHz, resulting in an antenna gain reduction of 0.41 dB.

The value of antenna gain chosen for Option 1 in Exhibit 1 is based on maintaining the same physical aperture size at 41 GHz as at 28 GHz. This results in a gain of 34.6 dBi, which includes the reduction in antenna effeciency to 50%. The antenna gain chosen for Option 2 in Exhibit 1 also includes the effeciency reduction factor.

Conclusion for 41 GHz Receiver Antenna Gain (with same size physical aperture):

CellularVision assumed value:	~~29 dBi~~
Correct Value:	34.6 dBi

Receiver Noise Figure

The increase in receiver noise figure from 6 to 8 dB when considering moving from the 28 GHz band to the 41 GHz band , as attempted by CellularVision, is not justified. The availibility of low noise devices with comparible noise performance in the 41 GHz band has been documented in filings to the Commission[8], and the assumption of a 6 dB noise figure for 41 GHz LMDS systems is completely reasonable.

[8] see, for example the Teledesic response to the NPRM, Appendix A, LMDS is Feasible in the 40.5 - 42.5 GHz Band, dated January 30, 1995, page 10, which states "developments in High Electron Mobility Transistor (HEMT) technology allows the use of amonolithic low noise amplifier state before the mixer. This makes achieving a receiver noise figures of 6 dB economically feasible."

Conclusion for 41 GHz Receiver Noise Figure

CellularVision assumed value: ~~8 dB~~

Correct Value: 6 dB

Path Loss / Maximum Range

The resulting impact of the corrected link budget parameters discussed above is dramatic. The CellularVision claim that the 41 GHz system "collapses" to 1.15 miles is shown to be baseless, and viable 41 GHz systems can indeed operate with the same 3 mile maximum cell size as the 28 GHz system. The "bottom line" of the link budget summary, (Exhibit 1), is shown to be the same for the 28 GHz reference system, and the two 41 GHz system options, namely a carrier to noise ratio of 16 dB, which provides the acceptable picture quality deemed necessary by CellularVision standards.

The Option 1 system summarized in Exhibit 1 maintains the same physical size hub transmitter antenna, the same size receiver aperture antenna, and the same 3 mile cell size: resulting in a slightly reduced link availibility of 99.8% for subscribers at the outer edges of the 3 mile cell. It should be pointed out that only subscribers in the outer edge of the cell are operating at this slightly reduced availability. If we assume a uniform distribution of subscribers in the cell, then all those subscribers inside of a 2.37 mile radius, or about 62% of all subscribers in the cell, will be at the 99.9% or better availability level! Furthermore, since half of the cells operate with vertical polarization, those subscribers with vertical polarization[9] will all operate with better than 99.8% (about 99.85%), hence over 80 % of all subscribers in the coverage area

[9] note that the links described in Exhibit 1 are for the worst case linear horizontal polarization, which is about 0.8 dB/mi more severe than linear vertical polarization, due to the non-spherical characteristics of rain drops.

will have near 99.9% operation!

The Option 2 system assumes the same conditions as option 1, except that the receiver antenna size is increased to maintain the 99.9% level with the 3 mile cell size. A receiver antenna of only about 15 inches will achieve the 99.9% level, without the need to reduce the cell size at all. It should be pointed out that the 15 inch antenna has the benefit of higher gain and reduced beamwidth, allowing for enhanced interference reduction and improved freqeuncy reuse, if required. In regard to any concern about the user acceptability of a larger antenna, it must be pointed out that antennas which are 18 inches is diameter are currently being marketed for the new "DSS" system in the United States, and are selling at an extremely fast rate.

One final point can be made regarding the link availibility values assumed for acceptable operation. The current industry standard for delivery of video programming is 99% of the worst month, which corresponds to 99.7% on an annual basis. If we ask the question, at what maximum cell size could we operate with the corrected 41 GHz parameters of Exhibit 1, we would find that a cell size of **3.5 miles** would give acceptable performance to the 99.7 % level for all subscribers in the cell! This is certianly a viable option to consider, since video delivery systems operating at the 99.7% level in the United States and Europe have attracted millions of subscribers.

We have demonstrated that LMDS systems operating in the 40.5 - 42.5 GHz band are viable and fully comparable in performance to LMDS systems proposed for operation at 28 GHz. In the next section, a comparison of costs for operation in the two bands will show that differential costs are low and are not a detriment to effective utilization of the 40 GHz band for LMDS.

3. COMPONENT COSTS

LMDS is cost effective in the 40.5-42.5 GHz band. With high volume production of 41 GHz equipment, costs are expected to be higher than 28 GHz equipment, but nowhere near CellularVision's claim of a 2 to 1 component costs factor.[10] In this section, the component costs factor is found to be 1.05 to 1.10. Moreover, this equipment price differential is expected to become negligible within a few years. For an LMDS system, total cell site costs include real estate, back-bone communications infrastructure equipment, RF equipment, installation, warranty, and long-term maintenance. A change in the RF broadcast frequency only affects the RF broadcast equipment cost, which is only a small percentage of the total lifetime cell site cost. This section presents the results of a RF components cost survey for the power transmitter, transmitter antenna, and receiver antenna. In the concluding section, the component costs factor of 1.05 to 1.10 is calculated by comparing the cumulative RF component price increase to the total lifetime cell site cost.

Other industry leaders have concluded similar results.

> "TRW has been and continues to be one of the nation's primary developers of electronics equipment and hardware for the millimeter wave bands. Through its years of experience in this area, TRW has gained a thorough understand of the properties and inherent strengths of the spectrum above 41 GHz that is proposed for allocation here. It can state with conviction that the technology that would drive LMDS at 28 GHz is not only available for 41 GHz, there is no appreciable cost difference."[11]

Additionally, Endgate who is developing LMDS receiver subscriber units states,

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[10] See footnote 2 ("LMDS is not Viable").

[11] See page 7-8 of Comments of TRW Inc., to ET Docket 94-124, RM 8308, dated January 30, 1995.

"Opening the 41 GHz band would result in slightly higher-cost millimeter wave equipment (as compared to 28 GHz equipment) because, as frequencies increase, the gain per state of amplifier decreases. Initially this will result in 41 GHz transmit and receive equipment on the order of 15% to 20% more expensive than equivalent 28 GHz equipment. Over a period of time this price differential will become insignificant in much the same way as the price differential between C-band and Ku-band systems has declined."[12]

Further proof that LMDS is cost feasible at 41 GHz is the United Kingdom prototype systems that are in development.

Additionally, if the United States implements an LMDS system similar to the global standard, equipment costs will be further reduced since the mass production quantities increase for the products on the global market. Moreover, US companies will produce the same equipment for both the US and the global market place without any additional costs; such strategies enable the US to be more competitive in the global market place.

Basic RF System Configuration

A basic block diagram of the RF equipment is provided in Exhibit 5. The IF signal, from the back-bone communications equipment, is fed into an up converter which converts the signal from IF to RF. The signal then passes through the High Power Amplifier (HPA) which contains the Traveling Wave Tube (TWT) amplifier to boost the signal to the high transmit power level. The signal then radiates from the omni-directional broadcast antenna to the subscriber units.

[12] See page 2 of Comments of Endgate Technology Corporation, to ET Docket No. 94-124, RM 8308, dated January 30, 1995, presented by Arent Fox.

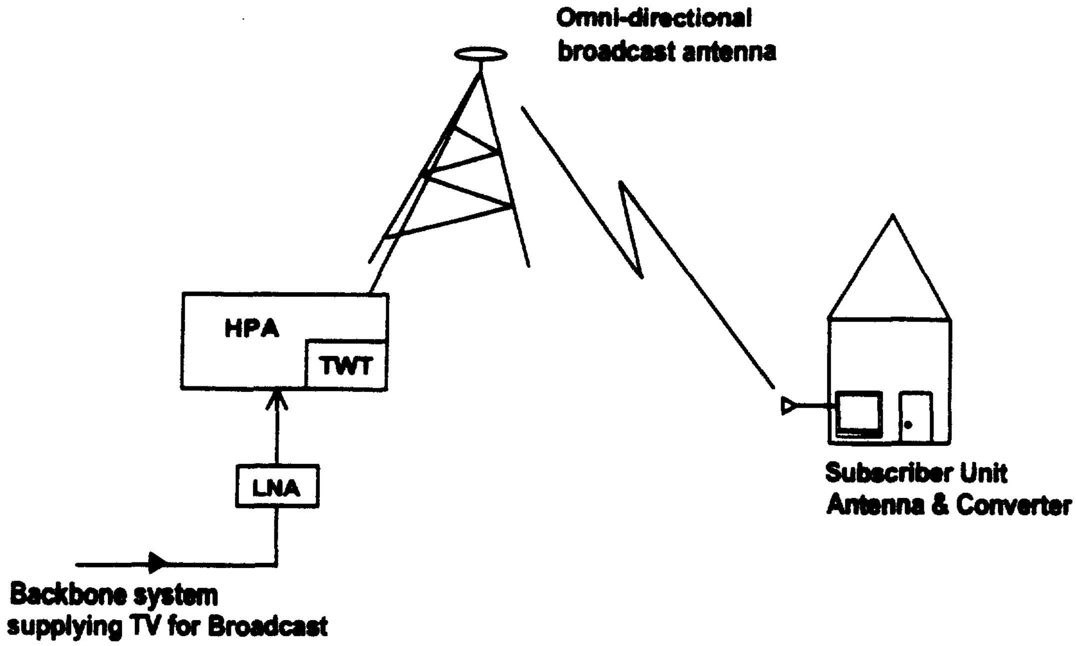

Exhibit 5 Basic RF system configuration.

For the RF component cost survey, typically piece part quantities needed to be determined. The Texas Instrument link budget assumed approximately 4000 LMDS cell sites in the US.[13] If each metropolitan area has two service providers, the number of LMDS cell sites doubles. Assuming cell site dual redundancy (for hot standby) and maintenance spares , the piece part quantity was chosen to be 10,000. Furthermore, since 41 GHz is the global allotment for LMDS and MVDS type systems, total global quantities would be much higher than 10,000 if LMDS is also at 41 GHz system. Each vendor was surveyed for equipment in the 27.5-29.5 GHz band the 40.5-42.5 GHz band. Since system planning is still very preliminary, all RF component cost quotes are Rough Order of Magnitude (ROM) prices.

[13] See Link Budget Table in Texas Instrument "LMDS/FSS-MSS Interference Analysis, Mitigation and Recommendations" Presentation on August 30, 1994 by Gene Robinson, P.E., to NRMC-41.

Power Transmitter Costs

The Cellular Vision 28 GHz LMDS cell site link budget[14] assumes a 100 W HPA, which contains a TWT, to transmit all 50 TV channels. Four different HPA vendors were surveyed for products in the 28 and 41 GHz bands as seen in Exhibit 6. At 28 GHz, the 100 W HPA cost ranges from $25,000 to $65,000 with an average of $45,000. At 41 GHz, the HPA cost ranges from $32,000 to $225,000 with an average of $97,400. The 41 GHz HPA has a maximum transmit power of 80 W, not 45 W as displayed in the CellularVision link budget.[15] The HPA price increases approximately 92.5% due to the frequency increase. This price increase must be compared to total cell site cost which is described in the Cumulative Cost Increase section at the end of this section.

Vendor	27.5 - 29.5 GHz	40.5 - 42.5 GHz	Issues
ETM	Current Product-80W 10: $75,300. 100: $68,100. 1,000: $63,100. 10,000: $58,700. Current Product-120W 10: $78,700. 100: $71,300. 1,000: $66,300. 10,000: $61,700.	Add 10% to price while subtracting 20-30% of power. Potential Product-55W 10,000: $64,600. Potential Product-80W 10,000: $67,900	Pricing with conservative learning curve. If true high quantity buying, the pricing would lower than these ROMs.
Varian	Current Product-120W (27.5-30 GHz) 10: $105,000.		
LogiMetrics	Current Product-120W 1: $100,000. 100: $80,000. 5000: $65,000.	Potential Product-80W 1: $275,000. 5000: $225,000.	41 GHz requires NRE.
Hughes	Current Product-100W 1: $65,000. 10: $62,000. 100: $53,000. 1000: $38,000. 10,000: $25,000.	Potential Product-65W 1: $81,000. 10: $77,000. 100: $66,000. 1000: $48,000. 10,000: $32,000.	41 GHz requires NRE. 1000 requires continuous TWT production.

Exhibit 6 HPA products (ROM pricing).

[14] See page 5 of footnote 2 ("LMDS is not Viable").
[15] See footnote 13.

Another option for transmission power is a single channel per carrier option in which a single power amplifier is required per cell site TV channel. Each amplifier provides 1 to 2 W of transmission power; since the power level is very low, solid state amplifiers would be implemented. A cell site would require 50 power amplifiers. The significant piece part price quantity would be 500,000. Two different vendors were surveyed as seen in Exhibit 7, and the vendors provided ROM prices for 10,000 pieces as their maximum. At 28 GHz, the power amplifier cost ranges from $1500 to $2500 with an average of $2000. At 41 GHz, the power amplifier cost ranges from $3000 to $4000 with an average of $3500. The piece part prices are expected to be further reduced at the 500,000 quantity. The power amplifier cost increases 75% due to the frequency increase.

Vendor	27.5 - 29.5 GHz	40.5 - 42.5 GHz	Issues
DBS Microwave	Potential Product-1W 1-4: $14,500. 100: $11,000. 1000: $3500. 10,000: $2500.	Potential Product-1W 1-4: $17,500. 100: $13,000. 1000: $5500. 10,000: $4000.	GaAs thin film design. Further cost saving by using a lower cost substrate material.
Hughes	Potential Product-1.5W 10,000: $1500.	Potential Product-1.5W 10,000: $3000.	

Exhibit 7 Power amplifier products (ROM prices).

In Exhibit 5, the up converter converts the signal from IF (output from the back-bone communication infrastructure equipment) to RF (input to the HPA). Two up converter vendors were surveyed as seen in Exhibit 8. At 28 GHz, the up converter cost ranges from $300 to $675 with an average of $490. At 41 GHz, the up converter cost ranges from $300 to $775 with an average of $540. The up converter price increases approximately 10% due to the frequency increase. And similar to the HPA, this price increase must be compared to total cell site cost which is described in the Cumulative Cost Increase section at the end of this section.

Vendor	27.5 - 29.5 GHz	40.5 - 42.5 GHz	Issues
Hughes	10,000: 300.	10,000: 300.	mixer, LO buffer amplifier, RF amplifier, filter (synthesizer provides LO and IF) IF is 1 GHz.
DBS Microwave	Potential Product 1-4: $4425. 100: $3300. 1000: $1100. 10,000: $675.	Potential Product 1-4: $5000. 100: $3795. 1000: $1375. 10,000: $775.	GaAs thin film design. IF is 1 GHz. IF amplifier, mixer, power amplifier, LO multiplier

Exhibit 8 Up converter products (ROM prices).

Transmitter Antenna Costs

The cell site broadcast antenna cost is unaffected by the change in RF broadcast frequency. While the 41 GHz antenna requires additional labor during manufacturing, the antenna requires less raw materials than a 28 GHz antenna. For large production quantities, a manufacturing tool (custom made for the specified antenna) would be implemented to reduce labor costs. According to antenna manufacturers, no price difference is expected for a 41 GHz omni-directional broadcast antenna than a 28 GHz broadcast antenna as seen in Exhibit 9.

Vendor	27.5 - 29.5 GHz	40.5 - 42.5 GHz	Issues
Prodelin	10: $3,000. 100: $800. 1,000: $150. 10,000: $50. 100,000: $42. (Assume tool used for 10K & 100k).	Same as 28 GHz. Higher frequency requires less material, but product is more difficult to manufacture.	NRE Engineer Design: $50,000. NRE High Volume Manufacturing Tool: $60,000.

Exhibit 9 Antenna products (ROM prices).

Receiver Antenna Costs

The LMDS receiver subscriber antenna would probably be either a patch antenna or a parabolic reflector dish. The receiver subscriber unit antenna is a low ticket item; for example, the 18" Direct Broadcast Service (DBS) antenna is a reflector which costs less than $15. The CellularVision filing implies a patch antenna solution.[16] Low cost patch antennas are available; but typically, a parabolic reflector costs less. The European MVDS system is implementing a 6 inch reflector with 32 dBi and 1.5 degrees pointing accuracy.[17] Furthermore, as frequency increases, the antenna size decreases which is more aesthetically appealing and reduces costs.

Cumulative Costs Increase

Exhibit 10 summarizes the RF component price increase and its effect on the total lifetime cell site cost. Each row, in Exhibit 10, presents price information for both the HPA and the up converter. The HPA and the up converter are the most expensive RF components for the cell site. The HPA prices are summarized from Exhibit 6 while the up converter prices are summarized from Exhibit 8. The broadcast antenna has not been included since no price increase is expected as seen in Exhibit 9. As previously stated since LMDS requires many cell sites, the production quantity of 10,000 was chosen.[18]

The price range for the 28 GHz equipment is presented in Row 1 of Exhibit 10, and the average price for the 28 GHz equipment is presented in Row 2. The

[16] See footnote 2 ("LMDS is not Viable").
[17] See "LMDS is Feasible in the 40.5-42.5 GHz Band," prepared by Teledesic, Appendix A, in Comments of Teledesic Corporation, to ET Docket No. 94-124, RM-8308, Dated January 30, 1995.
[18] See page 5 of footnote 2 ("LMDS is not Viable").

price range for the 41 GHz equipment is presented in Row 3, and the average price for the 41 GHz equipment is presented in Row 4. The percent price increase, due to the frequency increase, is presented in Row 5. The HPA cost increases 92.5% while the up converter increases 10%.

		HPA	Up Converter
1	Price range for 28 GHz at 10,000 piece part (ROM)	$25,000-$65,000	$300-$675
2	28 GHz average cost for 10,000 (ROM)	$50,600	$490
3	Price range for 41 GHz at 10,000 piece part (ROM)	$32,000-$225,000	$300-$775
4	41 GHz average cost for 10,000 (ROM)	$97,400.	$540
5	% Cost Increase due to Frequency Change	92.5%	10%
6	% 28 GHz equipment cost to RF cell site start up cost (RF equipment, install and 1 year warranty) @ 28 GHz (assume dual redundancy)	25.3%	0.245%
7	% Increase 41 GHz equipment to RF cell site start up cost	23.4%	0.0245%
8	% Increase due to equipment cost increase at 41 GHz to total lifetime cell site cost (real estate, back-bone communications infrastructure equipment, RF equipment, warranty, and long term maintenance)	**7.02%**	**0.00735%**

Exhibit 10 Summary of differential cost due to changing broadcast frequency.

The cost of the HPA and the up converter must be compared to total cell site cost for relevant overall price increase. For these calculations, the RF cell site start up cost includes the RF equipment, installation, warranty, and maintenance for 1 year; real estate, back-bone communication equipment, install, warranty, or long term maintenance costs are not included. At 28 GHz, dual redundant HPAs are approximately 25.3% of this RF cell site start up cost; and dual redundant up converters are approximately 0.245% of this RF cell site start up cost as seen in Row 6. Dual redundancy is assumed to provide hot standby (backup). Next, the percent increase due to the frequency increase is compared to the RF cell site start up cost. For the HPA, the percent increase is 23.4% while for the up converter the percent increase is 0.0245% as seen in Row 7. These increases must then be compared to the total lifetime cell site cost which includes real estate, back-bone communications equipment, RF equipment, installation, warranty, and long term maintenance. For these calculation the RF cell site start up cost is assumed to be 30% of the total lifetime cell site cost. As seen in Row 8, the percent cost increase for the 41 GHz HPA is 7.02% compared to the total lifetime cell site cost while the percent cost increase for the 41 GHz up converter is 0.00735% compared to the total lifetime cell site cost. Adding these two percent increases together gives an additional 7.03% to the total cell site cost; thus, the component cost factor for these two components is 1.07. Moreover, these percent cost increases should probably be compared to the total infrastructure cost including cell sites and hubs; this comparison would reduce the component costs factor even more. Therefore, the correct component costs factor is 1.05 to 1.10, not 2 as stated in the CellularVision filing.[19]

Although initially 41 GHz equipment will have a component cost factor of 1.05 to 1.10 over the 28 GHz equipment, the price differential is expected to become negligible within a few years similar to C-band and Ku-band equipment in the past. LMDS is cost effective in the 40.5-42.5 GHz band.

[19] See footnote 2 ("LMDS is not Viable")..

4. NON-LINE OF SIGHT CONSIDERATIONS

Degradation in System Coverage- Scattering Effects[20]

Filings by CellularVision claim that while the majority of subscribers are expected to have line-of-sight (LOS) to the hub and a small number of others may require dedicated passive reflectors or active repeaters, there is also an expectation that some un-specified share of subscribers without the benefit of direct LOS will receive signal of sufficient quality from building reflections (bounces). In the subject comments, CellularVision argues that the difference between the scattering effects in the 28 GHz and 42 GHz bands is enough to cause loss of coverage to these non-LOS subscribers, and therefore require smaller cells. Our analysis detailed below illustrates several technical problems with this argument and demonstrates that the scattering differences have a minimal impact on subscriber coverage. The CellularVision assertions neglect the available data in order to greatly exaggerate the frequency dependence, as a result, the reduction of cell size cited by CellularVision will not be necessary.

The first problem with the CellularVision argument is that *throughout* the millimeter wave bands (including 28 and 42 GHz) the amount of area without LOS but still receiving sufficient signal through alternative propagation mechanisms, such as reflection, is relatively small. We concur with the Teledesic comments on this proceeding[21] that the cell size will be limited not by rain attenuation, but by the desirability of maximizing the LOS area. Second, as we will show below, the differences in the characteristics of each non-LOS propagation mechanism between the 28 and 42 GHz bands are inconsequential, if discernible at all. Finally, though we contend that no cell-size reduction is

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[20] See page 9 of Appendix 2 cited in footnote 2 ("LMDS is Not Viable")
[21] See page 15 of Comments of Teledesic Corp. to ET Docket No. 94-124, RM-8308, Jan 30, 1995

necessary for any reason connected with changing the frequency, we must point out the unsubstantiated claim that the enormous factor of 7.3 reduction in cell size claimed for range/path loss reasons somehow cannot be applied to the scattering issue, and a *further* reduction by a factor of 2 is necessary. In light of evidence of the similarities between the two bands with regard to scattering, this is particularly extreme and demonstrates the willingness of CellularVision to distort reality.

In the following, we support the above three points with respect to each of the relevant propagation mechanisms: reflection, diffraction (two different approaches), and scattering. But first we address generally the exaggerated CellularVision claims regarding the impact of the wavelength dependence of these effects. A comparison with cellular telephony is enlightening. CellularVision proposes similar cell sizes to cellular telephony and operates in the same environments. Cellular telephony depends heavily on non-LOS mechanisms, especially multiple diffractions and reflections, to provide signal to the majority of the coverage area. However, the current CellularVision frequency of 28.5 GHz is more than 30 times larger than the UHF frequency of 900 MHz used by the cellular telephone network. By contrast, the increase from 28 to 42 GHz represents only a 50% increase in frequency or 33% decrease in wavelength, to 0.7 cm, a relatively small change. The LMDS service expects to provide coverage to a wide area using a frequency 30 times larger than that which has been proven to work in such an area, but claims that an additional 50% frequency increase is impossible. The variability alone of these mechanisms makes this difficult to prove. The CellularVision argument that the situation changes drastically only in this frequency range due to similarity of scale of wavelength to scale of surface characteristics is refuted by data provided here.

Reflections

Two independent studies reached identical conclusions regarding reflection properties in the subject frequency range. Experiments conducted by the NASA Lewis Research Center[22] were specifically designed to assess the impact of changing frequency from 28 to 42 GHz on quality of building reflections. Four incidence angles were tested on several different building materials. The conclusion was that "neither 28.5 GHz nor 39 GHz [representing the 40.5-42.5 GHz band] demonstrated consistently better reflection properties," because the difference between the average characteristics of the two bands was smaller than the natural variability of the effect. Since CellularVision correctly counts on signal bounces as the primary non-LOS mechanism, this result alone nullifies these CellularVision concerns about the frequency change.

In an earlier study, experiments conducted by the U.S. National Telecommunications and Information Administration (NTIA) and the U.S. Army measured the reflected energy from building materials at 28.8 GHz and 57.6 GHz[23]. Since building-reflected energy generally weakens with increasing frequency, the reflected signal level at 41.5 GHz will on average be mid-way between the levels measured at 28.8 and 57.6 GHz. The averaged measurements show 11.2 dB signal loss upon reflection at 28.8 GHz and 15.2 dB loss at 57.6 GHz, or 4 dB extra loss at the higher frequency. Assuming a linear dependence on frequency in this short frequency range, the reflection loss at 41.5 GHz may then be approximated as 13.2 dB, or about 2 dB more loss than at 28.5 GHz (less than 20% increase in signal loss). Note that these measurements were at zero incidence angle (straight on at the building face), where the greatest loss occurs. (At grazing incidence there is no reflection loss

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[22] See pages 7-9 of Comments of NASA to ET Docket No. 94-124, RM-8308, Jan 30, 1995

[23] See E. J. Violette, R. H. Espeland, R. O. DeBolt, and F. Schwering, "Millimeter-wave propagation at street level in a an urban environment," *IEEE Trans. Geoscience and Remote Sensing*, Vol. 26, No. 3, May 1988.

at either frequency, but also very little of the change in propagation direction necessary to provide signal to non-LOS subscribers.) The straight-on reflection loss measurements, however, also showed tremendous variability: sometimes the 57.6 GHz reflected signal was much weaker than the 28.8 GHz reflection, while in other cases (including brick surfaces) the higher frequency reflection was of higher power than the lower frequency reflection. Thus, this experiment also confirms the NASA conclusion that there was no *consistent* preference for one of the two subject frequencies with regard to reflection properties, and disproves the CellularVision assertions. Even the gross average 2 dB extra loss at 42 GHz cannot be the cataclysmic factor it is claimed to be. Few subscribers will be in the position of simultaneously lacking a LOS but receiving an unobstructed single-bounce signal, and also, by virtue of being well within the cell, possessing the necessary margin to withstand the reflection loss. While incrementally more subscribers could be covered by double-bounce signals, even fewer would be able to cover the ~20 dB (at 28 GHz) reflection loss.

CellularVision also refers to a "reduction in specular reflections", or lack of phase coherence, in the reflections from buildings at 42 GHz, without citing evidence. However, swept-frequency measurements in an urban area over a 66 MHz band, centered at 55 GHz (where the problem would be worse), found phase coherence in bandwidths greater than the maximum measurable 66 MHz in a large number of cases, and a minimum coherence bandwidth over all of the measurements of about 20 MHz[24]. If there were a phase incoherence problem with building reflections or scatter at frequencies above 28 GHz, as alleged by CellularVision, it would show up in this study as a small coherence bandwidth. The study concluded that, "from a propagation point of view, there is no

[24] See H. J. Thomas, R. S. Cole, and G. L. Siqueira, "An experimental study of the propagation of 55 GHz millimeter waves in an urban mobile radio environment," *IEEE Trans. Vehicular Technology*, Vol. 43, No. 1, Feb 1994.

fundamental difficulty in implementing a wideband short range communication system in the millimeter wave band."

Diffraction

In addition to reflections from broad building surfaces, there are two forms of diffraction that provide signal in areas without a line-of-sight: scattering by a building corner or edge, and "bending" of the direct signal around an obstacle. The former is a function of the electrical properties of the building material, as quantified by the reflection loss. Our calculations of this diffractive scattering employed the uniform geometric theory of diffraction (UTD)[25] adapted for imperfect conductors[26] using reflection loss values of 11.2 dB at 28.5 GHz and 13.0 dB at 41.5 GHz, as derived above. This procedure is complex and is therefore attached as a separate appendix[27]. The results predict diffracted fields with at least 26 dB loss at 28.5 GHz (excluding the short regions of transition discussed below) and 28 dB loss at 41.5 GHz, and a pattern of diffraction, or distribution of signal energy, that is essentially the same at the two frequencies. Thus there is only a 2 dB difference between the two bands, and a signal level in either case that is so low as to be mostly useless.

The second type of diffraction noted above is computed by a technique known as Fresnel-Kirchhoff, or infinite knife-edge diffraction. This approach neglects any scattering (re-radiation) from materials (shown above to be very small in our situation), and instead uses the concept of secondary sources of radiation in space (Huygens sources) to describe the readily observed phenomenon of wave

[25] See W. D. Burnside and K. W. Burgener, "High-frequency scattering by a thin lossless dielectric slab," *IEEE Trans. Antennas and Propagation*, Vol. AP-31, No. 1, Jan 1983.
[26] See V. Erceg, A. J. Rustako, and R. S. Roman, "Diffraction around corners and its effects on microcell coverage in urban environments at 900 MHz, 2 GHz, and 6 GHz," *IEEE Trans. Vehicular Technology*, Vol. 43, No. 3, Aug 1994.
[27] See Appendix A of this document

propagation around obstacles. This is the recommended approach of the ITU-R for diffraction by obstacles (such as terrain) in land-based radio systems[28]. As distinct from the UTD method, Fresnel-Kirchhoff diffraction is a theoretically derived model for the transition between LOS and non-LOS, where signal level falls off smoothly as the degree of shadowing increases. This diffraction model has a frequency dependence which produces faster fall-off of signal level at higher frequencies. However, the same two conclusions of the UTD diffraction analysis are evident here: 1.) The difference between the results for 28 and for 42 GHz are small; 2.) At either frequency, the diffraction loss gets large very quickly.

Exhibit 11 makes it clear that there is only a very small region in which the diffraction field is relevant at all, a short transition between LOS and the point where diffraction field is so low that the receiver is completely blocked. This figure illustrates the Fresnel-Kirchhoff diffraction field at 28 GHz, 42 GHz, and as a reference, 914 MHz, in the UHF cellular radio band. The diffracting obstruction intervenes at a point 30 m from the receiver location (typically the greatest obstruction is produced by the building across the street) and 1 km from the transmitter. The LOS signal does not end abruptly where the shadowing is zero, but falls off smoothly from well before the shadow boundary (at any frequency, the knife-edge diffraction loss is 6 dB at the shadow boundary.) At a subscriber position 28 cm into the shadow, 10.3 dB diffraction loss (relative to LOS) is calculated at 28.5 GHz and 11.1 dB at 41.5 GHz, giving 0.8 dB extra diffraction loss at the higher frequency, a negligible amount in light of the much stronger geometrical dependence. This scenario was chosen such that the diffraction loss was near the maximum tolerable amount, and yet the LOS can be achieved by moving the subscriber antenna only 28 cm! Certainly it is the rare case where the diffraction loss is within the tolerable range and the transition region is

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[28] See Recommendation ITU-R PN. 526-3, "Propagation by Diffraction," ITU, Geneva, 1992.

relevant at all. Moreover, small adjustments of the placement of the receiver antenna produce large differences in diffraction loss that easily overwhelm the small difference between the 28 and 42 GHz bands.

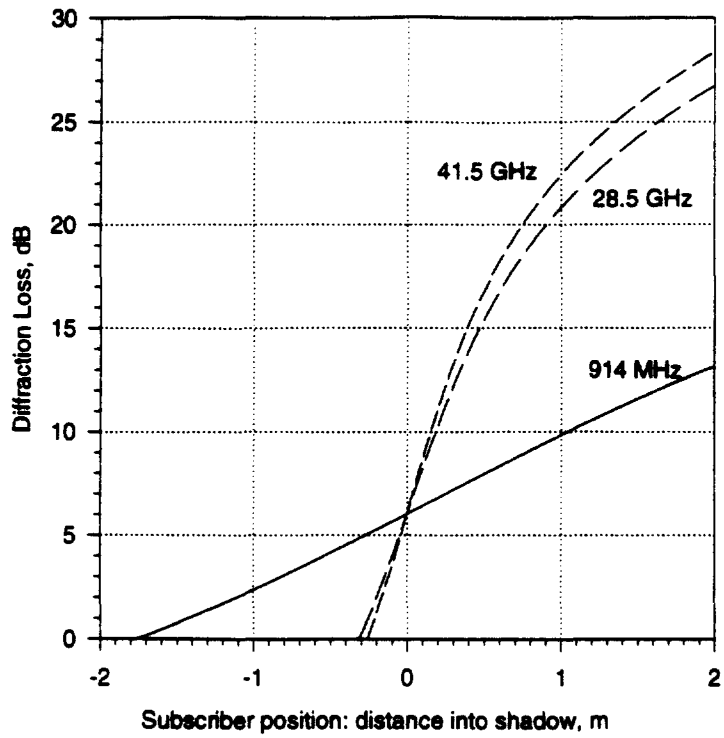

Exhibit 11. Fresnel-Kirchhoff (knife-edge) diffraction loss in transition region

Scattering

The final mechanism for change of propagation direction (in the land-based environment) is non-specular scattering. The term "reflection" refers to the specular (mirror-like) redirection of energy from a surface, where the angle of incidence equals the angle of reflection. The geometry of buildings do not always provide specular opportunities, however, there will also be energy scattered from the surface in non-specular directions. Scattering measurements on real buildings in England at 9.4 GHz[29] (which should have higher levels of scattered field) found that "In non-specular conditions, the scattering coefficient

[29] See E. N. Bramley, S. M. Cherry, "Investigation of microwave scattering by tall buildings," *Proceedings IEE*, Vol. 120, No. 8, Aug 1973.

was typically of order -30 dB," demonstrating the low level and resultant irrelevance of non-specular scattering. Exhibit 12[30] shows the measured loss, L, in dB as scatter points (the lines refer to various models not discussed here).

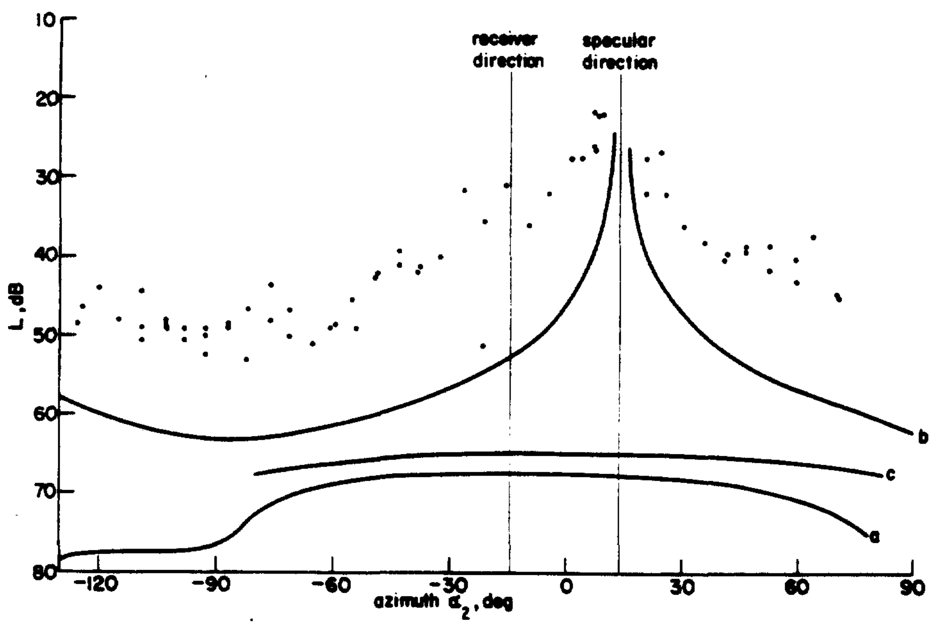

Exhibit 12. Non-specular scattering measurements (dots)

Summary

Thus, differing reflection/diffraction/scattering characteristics between the 28 and 42 GHz bands cannot reasonably make the difference between adequate and inadequate provision of signal to non-LOS subscribers, despite the claims of CellularVision. In either band, the cell will have to be limited in size in order to keep the maximum portion of the area line-of-sight, as a result, rain loss will not be the limiting factor on cell size, but rather the desirability of line-of-sight.

<u>Conclusion for 41.5 GHz Degradation in System Coverage - Scattering Effects</u>

CellularVision assumed value:	Cell size reduction by factor of 2
Correct value:	No cell size reduction

[30] See id., Figure 4.

5. ADDITIONAL COST / PERFORMANCE FACTORS

Tree and other Foliage Attenuation[31]

The available data do not support the CellularVision conclusion that foliage losses "will increase on a given path by an amount between 3 and 8 dB in moving from 28 GHz to the bands above 40 GHz." An in-depth experimental study of foliage attenuation at 9.6, 28.8, and 57.6 GHz by the U.S. NTIA and the U.S. Army concluded:

> "The measured data also shows a clear trend for the vegetation loss to increase with frequency. This increase seems to occur in a smooth but not necessarily uniform fashion. In particular, for trees in leaf, the foliage loss increases substantially as the frequency is raised from 9.6 to 28.8 GHz. But it increases at a much slower rate between 28.8 and 57.6 GHz, the additional loss amounting to a small correction only."[32]

While the loss at 28.8 GHz certainly represents the loss in the 27.5-29.5 GHz band, it must be expected that loss in the 40.5 to 42.5 GHz band will be somewhat less than that measured at 57.6 GHz, and the additional loss over the 28 GHz band will be even less than the "small correction" cited above. Other references offer similar assessments, such as "3 to 5 dB per meter of foliage in the 44.5/20 GHz operating regime,"[33] which lumps the entire frequency range from 20 to 44.5 GHz together. Note Exhibit 13[34] which shows measurements on the same trees in winter (without leaves) and in summer. Differences of 3-4 dB between 28.8 and 57.6 GHz are seen for the bare trees, but the two frequencies

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[31] See page 10 of <u>LMDS is Not Viable</u>

[32] See F. K. Schwering, E. J. Violette, and R. H. Espeland, "Millimeter-wave propagation in vegetation: experiments and theory," *IEEE Trans. Geoscience and Remote Sensing*, Vol. 26, No. 3, May 1988, pg. 366.

[33] See Telecommunications Review, 1993, pg. 125.

[34] See Schwering et al., Figure 3(c).